Cryogenic Optical Test Plan for the AMSD Program

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May 22, 2002

MSFC Responsibilities

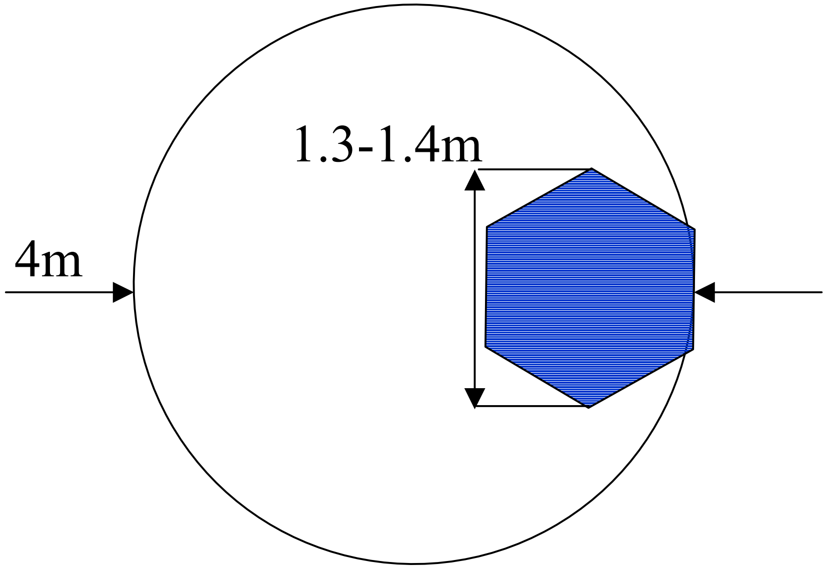
- Develop and/or analyze cryo optical test requirements.
- Design & assemble system (instrumentation, hardware, software, procedures) to accomplish cryo test requirements.
- Install & check-out optical test system in XRCF.
- Operate optical test system during cryo testing.
- Conduct appropriate data reduction & analysis of cryo test data with the purposes of: (1) cross-checking vendor results, (2) supplying measurement data to MSFC modeling team, & (3) aiding vendor in understanding/interpreting results.
- Transfer knowledge gained to the appropriate flight system teams (government & commercial) to ensure mission success.
- **All steps above require close interaction with AMSD vendors.**

AMSD Optical Characteristics

	Ball	Kodak	Goodrich
Diameter	1.4 m	1.4 m	1.3 m
Material	Be/ Comp	ULE Sandwich/ Comp	SiO2 Isogrid/ Comp
# Actuators	4	16	37
Areal Density		<15 kg/m2	
Operating Temperature		30-55 K	

AMSD Prescription

- Off-axis segment of paraboloid with vertex ROC of 10 m.
- Hexagonal, 1.3-1.4 m diameter (point-to-point) physical aperture. Clear aperture extends to within 15 mm of edge.
- Outer flat edge is tangent to edge of 4 m diameter parent.



AMSD Optical Test Requirements

Table 1 – AMSD Optical Requirements		
Item	Requirement	Units
Shape	Hexagonal	
Areal Density	< 15	kg/m^2
Petal Size	1.2-1.5	m (point to point)
Radius of Curvature	**(2)**	
Prescription**(3)**	Off-Axis Parabola	
Total Surface Error**(4)**		
p-v	250/100	nm
rms	50/25	nm
RMS Micro-Roughness **(5)**	4/2	nm
Operating Temperature	35 +20/-5	K
Survival Temperature	25 to 353	K
Stiffness	**(8)**	

Requirements to be verified at cryo are highlighted in yellow.

AMSD Optical Test Requirements

(2) Radius of Curvature. Absolute ROC shall be 10 m ±1 mm. All residual surface figure errors resulting from active control to achieve the desired ROC must be included in the overall wavefront error. Actuator stroke and resolution must be demonstrated such that when incorporated into the mirror system they achieve a (0.00004 m)/D^2 ROC matching over the ROC tolerance band. The contractor is also required to test for ROC change over the operating temperature range of the AMSD as specified in the table. Active control, if required, can be implemented to correct the ROC at each temperature range extreme after change in ROC data is acquired.

(3) Prescription. The prescription for the off-axis design is a parabola with vertex radius of curvature equal to 10 m. The hexagonal aperture of width D (point-to-point) will have its outer edge tangent to a 4 m diameter circle centered on the parent vertex.

(4) Total Surface Error. The PV & rms requirements for total surface error are the first two numbers listed in the table (250 & 50 nm). The second two numbers (100 & 25 nm) provide goals for the contractor in the development of this mirror technology and are desirable, but not mandatory. Active control of the AMSD mirror may be implemented to obtain the required surface figure. The total surface error requirement must be met over the clear aperture of the mirror. The clear aperture requirement must be within 15 mm of all physical edges with the goal to meet the surface error requirement over the physical aperture.

Total Surface Error (TSE) shall be defined such that it includes effects from low-spatial frequency (figure), mid-spatial frequency (ripple), and high-spatial frequency (micro-roughness) errors. Figure errors of piston, tilt, and defocus/power (usually the first 4 Zernike terms) are not included in this definition and are to be removed from the data before TSE is determined. Contractor must measure the mirror in such a fashion that they can accurately generate two-dimensional (2-D) power spectral density (PSD) curves of the mirror surface error as a function of spatial frequency. A composite, average PSD curve will be generated that will cover the entire spatial period range from full aperture down to approximately 1 micron. It is acknowledged that contractor may use several different metrology instruments to obtain the necessary data and that some spatial periods, by necessity, will be determined using sound statistical sampling methods. No point on this composite, average PSD curve shall deviate from its local, nominal average value by more than a factor of 10.

PV & rms figure error requirements shall be verified using full-aperture interferometry data. Spatial frequencies included in this figure error analysis shall correspond to those provided by the 5th through the 37th Zernike terms, as defined by the particular set of Zernike polynomials named FRINGE. The first four Zernike terms in this set (corresponding to piston, tilt, and defocus/power) shall be removed from the data set before calculating this figure error.

(5) RMS Micro-Roughness. Average micro-roughness or high-spatial frequency error shall not exceed 4 nm rms as indicated in the table. The second number (2 nm) provides a goal for the contractor in the development of this mirror technology and is desirable, but not mandatory. Spatial periods included in this micro-roughness error analysis shall correspond to 1 mm down to 1 micron.

(8) Stiffness. For structural design, the AMSD shall be designed to at least a minimum fundamental frequency shown in the figure below as supported on a kinematically optimized three-point mount mentioned above. Modal analysis and testing is required to define the first 5 modes of the optical surface.

Derived AMSD Cryo Optical Test Requirements (Total Surface Error)

	Requirement	Goal
Total Figure, PV	250 nm (λ/2.5)	100 nm (λ/6.3)
Total Figure, rms	50 nm (λ/13)	25 nm (λ/25)

TSE is defined to include surface errors in the spatial wavelength band of 1 micron to full-aperture (1.4 m).

For IPI, f/5 beam fills 1Kx1K detector. CGH uses only f/6.9 to fill a 1.45 m AMSD (rest is for alignment features on null), yielding about 725 pixels across a 1.45 m AMSD, or 2 mm/pixel. Thus, IPI can measure surface errors with spatial wavelengths down to about 4 mm.

Will measure surface errors in 1 micron to 4 mm range only at ambient temperature (assumed to be constant with temperature) using profilometer. A Wyko profilometer with a 2.5X objective can measure errors up to a spatial wavelength of 8 mm, giving overlap.

Will then combine resulting PSDs to get the final cryo TSE.

Will measure figure at 30 & 55 K with ROC set to 10 m ±1 mm at each temp, and at 35 K with ROC set to 10 m, 10.001 m, & 9.999 m.

Derived AMSD Cryo Optical Test Requirements (ROC)

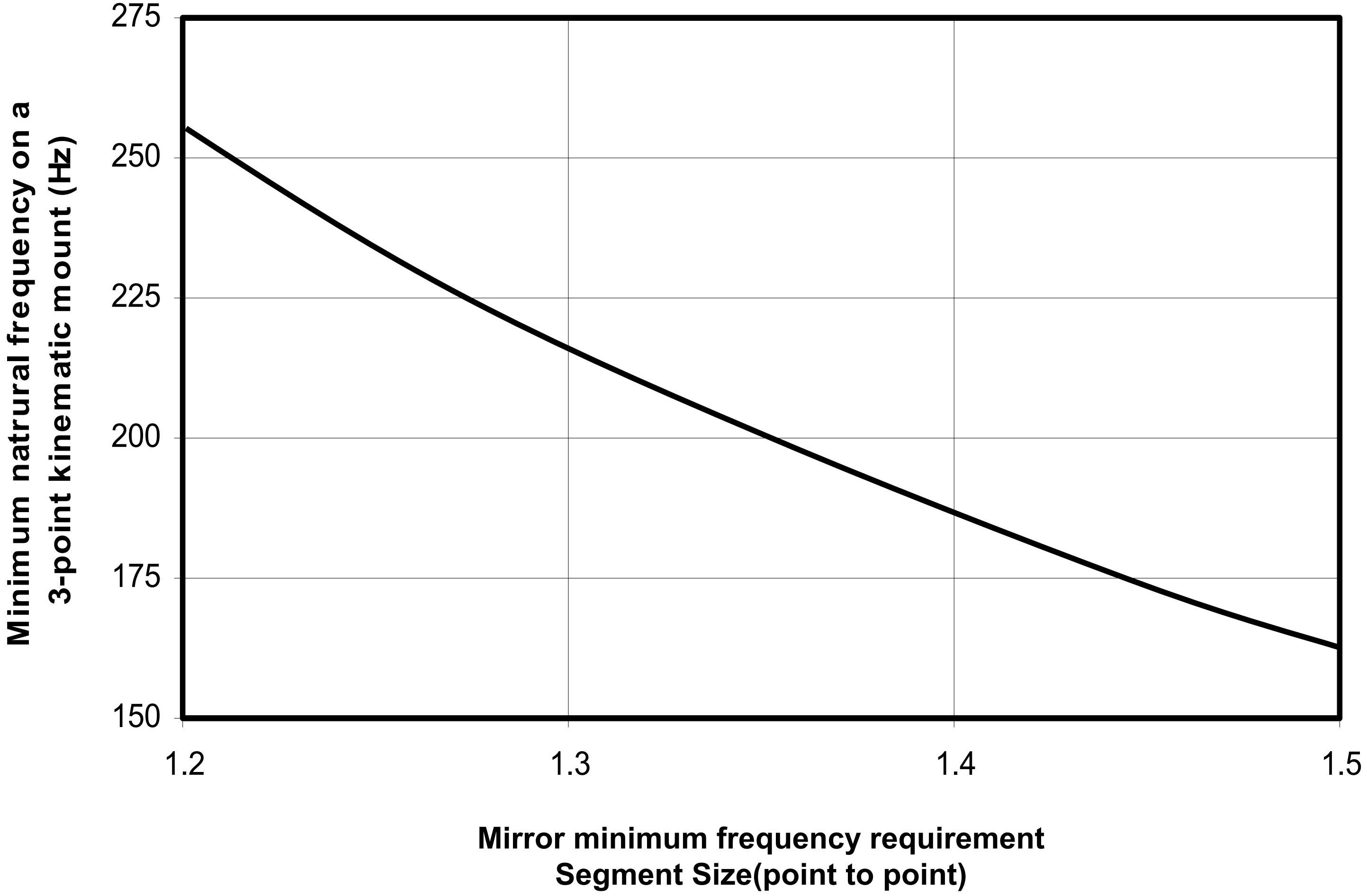
	Requirement	Goal
ROC, absolute	±1 mm	NA
ROC, adjustability	±20-24 μm	NA

ROC is defined as parent or vertex ROC, not best-fit ROC of segment.

Suggested Measurements:

- ROC at 35 K after actuator optimization.
- ROC at 30 & 55 K without any actuator changes between.
- ROC at 30 & 55 K after actuator optimization at each temp if required to meet 10 m ±1 mm.
- ROC adjustability about 10 m at 35 K.
- ROC adjustability about 10.001 m at 35 K.
- ROC adjustability about 9.999 m at 35 K.

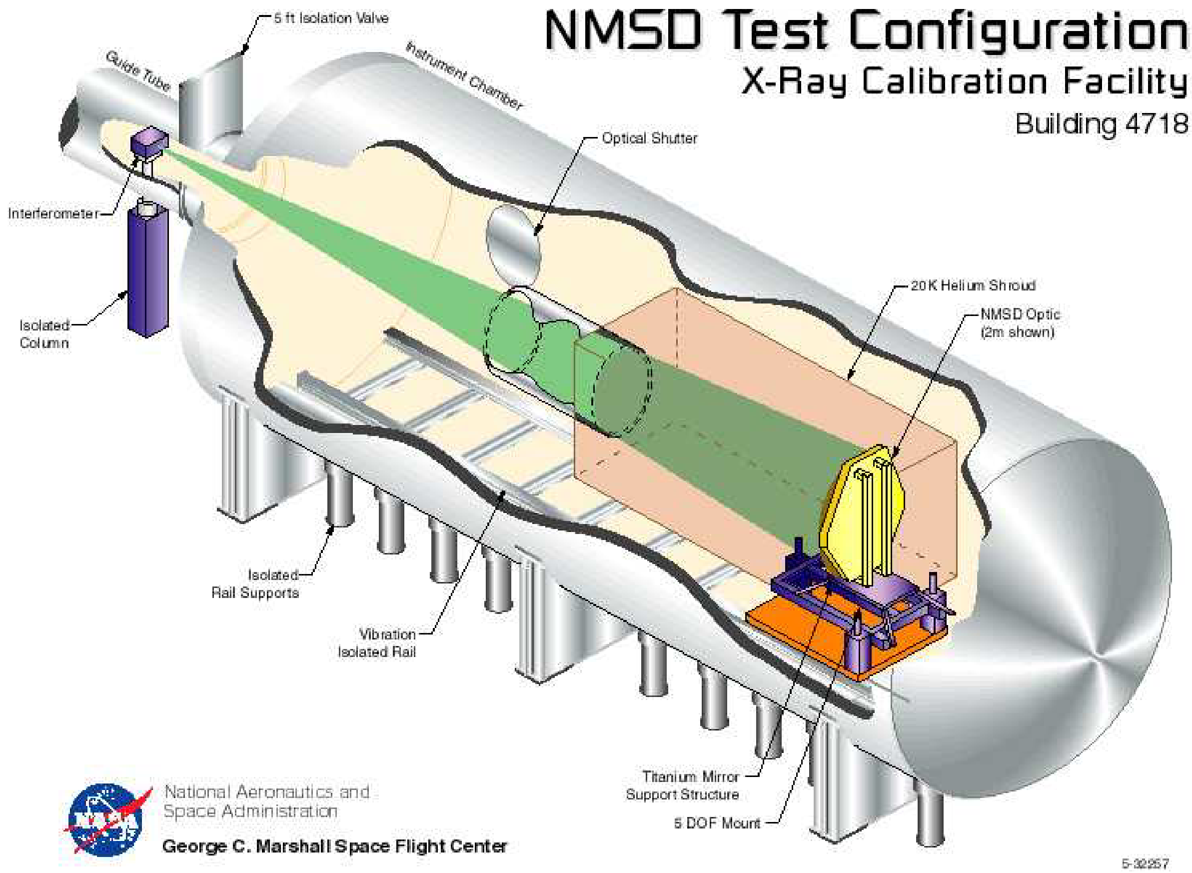
Derived AMSD Cryo Optical Test Requirements (Stiffness)



Other Desired AMSD Cryo Optical Test Measurements

- Figure error outside operational temperature range of 30-55 K.
- Conic constant error.
- Parent vertex location with respect to segment fiducials.
- Figure stability at a given temperature.
- …

XRCF Schematic



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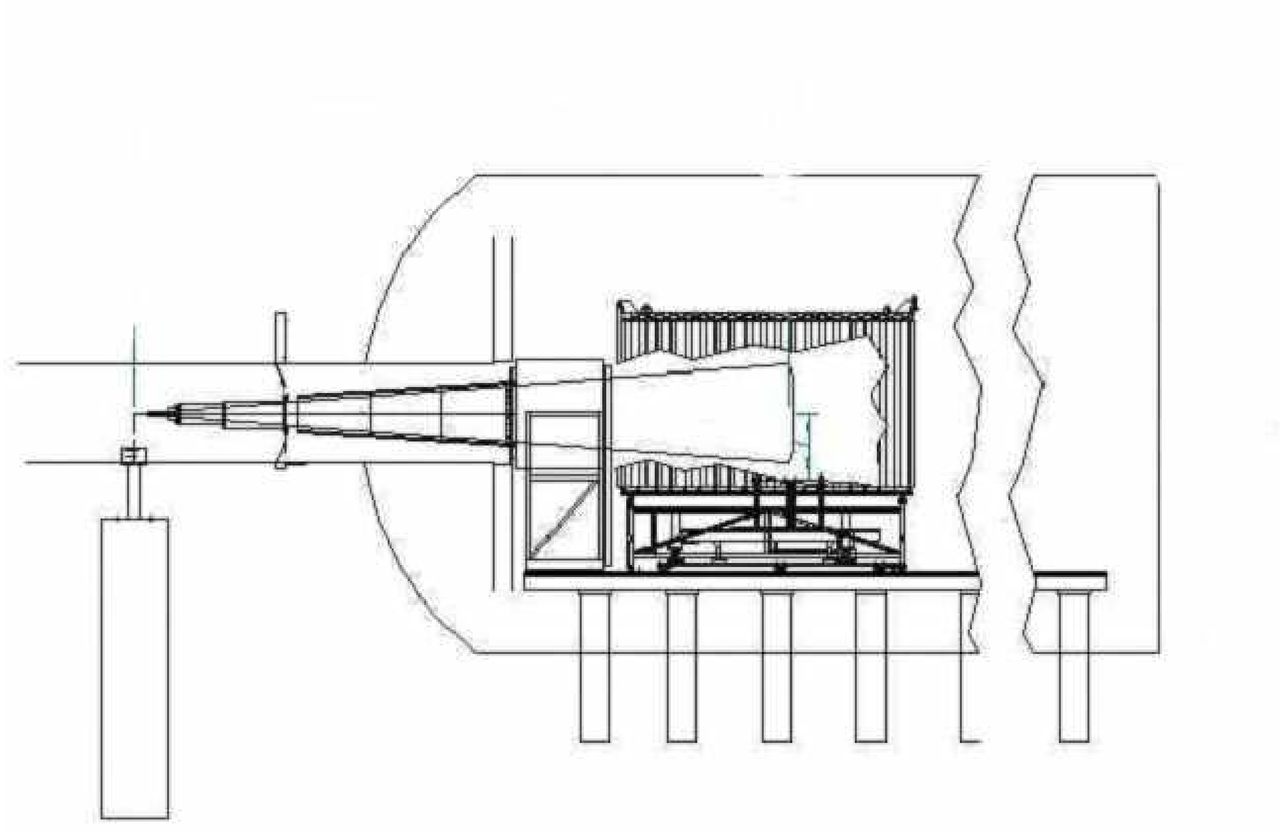


Current AMSD OTS Design

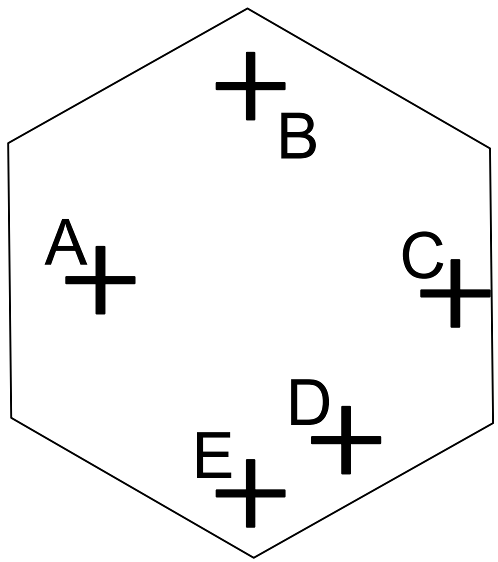
- Instantaneous Phase-shifting Interferometer (IPI with 1Kx1K output or PhaseCam with 0.5Kx0.5K output) located atop 6-DOF stage (hexapod) on stabilized pier in guide tube at 1 ATM pressure.
- Computer-generated diffractive null corrector (includes window aberration correction).
- 600 mm diameter extension installed from chamber gate valve to within 600 mm of pier center with 150 mm diameter clear aperture window (16 mm thick BK-7).
- Next-generation Leica ADM laser distance meter used to measure ROC.
- 5-DOF support for mirror.

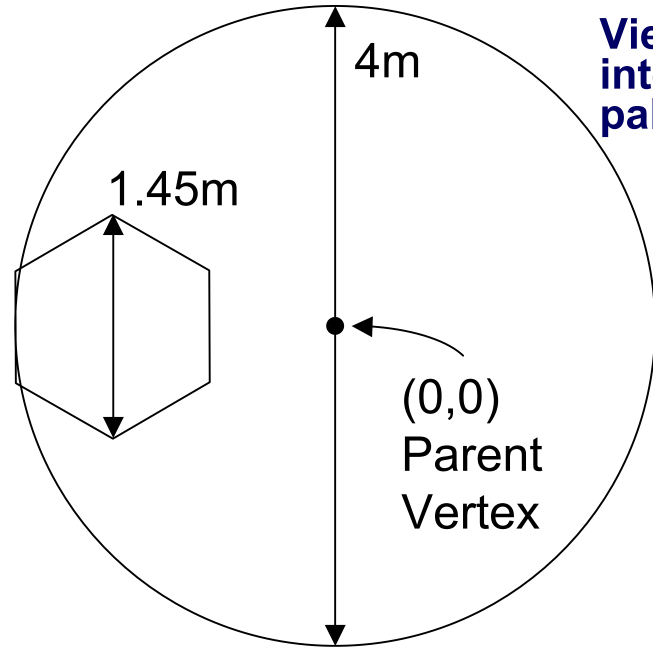
Modal Testing Plan

- Modal testing will be accomplished with one or both of the following methods:
  - Accelerometers to measure mirror response when exposed to controlled vibration inputs.
  - Stroboscopic interferometer to measure mirror surface shape as a function of controlled vibration inputs.
  - Will adopt at least one method to work at both ambient and cryogenic temperatures.

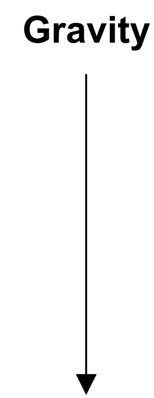
AMSD-to-XRCF Interfacing

A = (-1900,0)
B = (-1393,550)
C = (-886,0)
D = (-1155,-412)
E = (-1393,-550)





View of AMSD from interferometer pallet in XRCF.



- Interferometer/null aimed at center of off-axis segment.
- Fiducials for XRCF testing to be specified to vendor, who will apply.
- Parent vertex location & segment tilt tolerances specified with respect to chamber centerline so that mirror is within capture range of XRCF mirror & interferometer pallet adjustment systems after mounting.
- Surface error data format to be specified by each vendor.

AMSD Data Reduction & Analysis

- Figure error measurement results will be provided to each vendor in acceptable format. Pupil distortion correction to be done by MSFC if desired by vendor.
- Reduction & analysis of raw results to be performed largely by vendors (gravity back-out, influence functions, etc).
- MSFC team will selectively check/verify vendor results.
- MSFC team will support vendors in investigating anomalous results.
- MSFC team will support measurement-model correlation efforts.
- MSFC team will perform analyses of interest as needed.

AMSD Optical Test Team Schedule

- Distribute first draft of AMSD-XRCF interface definition document (IDD) – 6/1/02
- Receive final vendor cryo test plan inputs – 6/1/02
- Finalize & publish AMSD Cryo Test Requirements – 6/7/02
- Receive final modeling team cryo test plan inputs – 6/7/02
- Complete & publish AMSD Cryo Test Plan & final IDD – 6/17/02
- Complete experiments to support development of surface figure & ROC measurement procedures – 6/30/02
- Finalize surface figure & ROC measurement error analyses – 7/12/02
- Finalize optical test system design & receive remaining hardware – 7/12/02
- Complete review of methods & plans – 8/20/02

AMSD Optical Test Team Schedule

- Assemble/install optical test system – 9/9/02
- Complete first TRR with each vendor – 9/16/02
- Update hardware, software, procedures as necessary based on reviews – 10/17/02
- Complete AMSD Cryo Test Procedures – 10/17/02
- Conduct first AMSD cryo test – start 11/19/02